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DEVICE AND METHOD FOR DOSING AND TRANSPORTING DRY UREA,
ESPECIALLY DURING THE IMPLEMENTATION OF THE SCR METHOD IN
MOTOR VEHICLES

Background of the Invention:

The present invention relates to a device and a method for
dosing and transporting dry urea according to the definition
5 of the species in Claim 1 and Claim 27.

Technical Area

A large increase in population, increased industrialization
10 and rising amounts of traffic lead to a concentration of
contaminants in the environmental air that has assumed
critical proportions. In this connection, nitrogen oxide
emissions are of special importance, and these may be
attributed in large measure to the combustion of gasoline
15 fuels and Diesel fuels in automobiles. Nitrogen oxide
emissions contribute, among other things, to increased ozone
concentrations at ground level.

In order to counter this critical development, and based on
20 repeated tightening of contaminant limiting values by
lawmakers, automobile manufacturers have constantly made
efforts to decrease nitrogen oxide concentrations that are
created during the operation of a motor vehicle. In this
context, a promising note is the application of the SCR
25 method, known from industrial installations, in which ammonia
is added to the exhaust gas stream. In this context, the
ammonia reacts with the nitrogen oxides to form nitrogen,
carbon dioxide and water.

Because of the danger potential relating to the ammonia, carrying ammonia along in a motor vehicle is a problem. Therefore, the idea has come up of producing ammonia, in a quantity exactly required for the chemical reaction, from urea.

Background Information

This idea was taken up, for example, in DE 40 38 054 A1, in which an aqueous urea solution is carried along in a container in the motor vehicle, and, with the aid of a hydrolysis catalyst, is split into ammonia and carbon dioxide. In practice, however, various problems come about from the use of an aqueous urea solution. Carrying along aqueous urea not only assumes a corresponding space availability for the tank required for this, but also increases the overall weight of the motor vehicle. Additional disadvantages come about with reference to the wintertime suitability of a vehicle, because of the relatively high freezing point of the urea solution. Besides, in the operation of the motor vehicle, the water proportion of the urea solution has to be evaporated, so that this energy is no longer available to increase the reaction temperature. Finally, the production of aqueous urea solutions is expensive, since they are made using deionized water so as to avoid deposits.

Therefore, in the past, people have gone over to the idea of using dry urea for producing ammonia, which, after it has been brought to a powdery consistency, is transported to the place of application using a carrier air stream. However, the assumption for this is that the urea is in a free-flowing condition. However, this property is greatly impaired if the dry urea is exposed to moisture, high temperatures or mechanical pressure, since then the baking together of the urea particles may occur. Additional problems come about

while transporting solid substances by their inclination to form bridges, which may later cause clogging.

For example, from EP 0 615 777 A1 such a method and an appertaining device are known. In this example, urea is supplied from a storage vessel, using a precision dosing unit, to a carrier air stream. The precision dosing unit works according to the principle of a feeding screw, a change in dosing being achieved via a change in the rotary speed of the feeding screw. The solid urea is either already present in powder form in the storage vessel or, if bigger particles are being used, is conveyed to a millwork before being transported. In order to prevent the absorption of moisture, it is suggested there that one should pack the urea under the exclusion of humidity of the air, and to open the package only after inserting it into the storage vessel.

It is true, though, that using loads of urea that are packed in an air-tight manner is very expensive, since the urea first has to be packed in an air-tight manner, excluding moisture. In addition, the individual packages must not be too large, since in the course of time the urea absorbs moisture, even in the storage vessel, because of its hygroscopic properties. However, smaller urea portions call for frequent refilling of the storage vessel, which is of little convenience to the user of a motor vehicle.

In order to overcome these disadvantages, DE 197 54 135 A1 proposes carrying the urea along in a solid monolithic structure. Depending on requirements, using a removing device, the appropriate quantity of urea is continuously removed from a block, if necessary, the urea is finely ground if the particles are still too big, and the powdery urea is then fed to a carrier gas stream for transport. The removing device is a rotating disk or roll fitted with bristles,

abrasive grains, knives or milling tools. By changing the advancing speed of the removing device with respect to the urea block, the dosing quantity may be varied.

5 Using this procedure, it is true that the problem of baking is solved, however, other problems remain. Thus, in this case, the prepreparation of the urea to form monolithic blocks is necessary, which means a corresponding preliminary
10 expenditure. An additional disadvantage comes about due to the use of the removing device described there. During removal from the urea block, unavoidably urea particles of different sizes are produced. This has the result that the urea quantity supplied to the system varies as a function of the particles. Exact dosing in accordance with instantaneous
15 requirements, if at all possible, may be done only within wide boundaries.

DE 197 54 135 A1 thus proposes using an additional millwork by which the particles removed from the urea block are milled
20 down to a powder. This, however, has the disadvantage that the conversion of the urea block to powdered urea represents an additional preinserted method step which negatively influences the reaction time of the overall system, that is, the system becomes too inert. Because of that, the
25 requirement for ammonia conditioned upon the load change is not able to be satisfied in the short run, or, in the short run, an oversupply is created.

Detailed Description of the Present Invention

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Based on this background, the present invention is based on the object of stating a method and a device for dosing and
35 transporting dry urea, which permit exact dosing of the urea within wide ranges of quantities in a greatly dynamic manner.

An additional object is the reliable transport of the urea to the processing location.

This objective is attained by a device having the features of Patent Claim 1 as well as by a method having the features of Patent Claim 27.

Advantageous embodiments of the present invention are described in the subclaims.

The present invention is based on the idea of using urea, for carrying out the SCR method, in a form that is already available in large quantities. Thus, urea is applied in large volume to agriculturally used areas, for fertilization. The urea from the fertilizer industry corresponds in its composition, form and dimensions to the requirements of the present invention, that is, it is available in the dry state in spherical or sphere-like shape. Such urea is also designated by the technical term pellet. However, within the sense of the present invention, the term pellet is not limited to a spherical or sphere-like shape, which only represents a preferred form in which the urea is used. Rather, the term pellet used in the sense of the present invention includes, in general, grainy material which might be broken up just as well.

As a result of the mass production in large industrial plants for agricultural use, such urea is available in large quantities as starting material for the present invention, and is therefore extremely cost-effective. Any size is basically possible as the setpoint size for the individual pellets. However, as the size of the pellets decreases, a finer gradation for dosing may be achieved. If the dimensions of the pellets otherwise used for fertilizing differs too greatly from the setpoint value of the present invention, simply

passing the pellets through a screen will yield a suitable size fraction. A preferred size fraction includes pellets having deviations from the setpoint size in the range of about 5 %. The setpoint size preferred by the present invention has a diameter of 1 to 3 mm.

However, the present invention is not limited to using urea in pellet form, but includes, at the same time, a device using which it is possible to supply these pellets from a storage vessel in a predefined dosing to the conversion process to ammonia. This takes place by isolating the pellets and subsequently passing them on to a carrier air stream, which performs the further transport. In this manner of proceeding, therefore, the smallest possible dosable unit quantity is determined by a pellet. By sequential isolation and subsequent transport of the pellets, a transport flow is produced in which the speed of the isolation and of the transport are decisive for the dosing.

According to one advantageous specific embodiment of the present invention, the isolation and supplying of the pellets to the carrier air stream take place with the aid of a disk, ringwheel or a hollow cylinder section which has(have) a plurality of receiving elements. By the rotation of the disk, ring wheel or the hollow cylinder section, the receiving elements are alternately brought into a position for filling and a position for blowing out. The rotational movement of the disk, ring wheel or the hollow cylinder section may be performed in a simple manner by a rotary drive, such as an electric motor. The change in dosing takes place, in this context, in a simple manner, by changing the rotary speed. This way of proceeding makes possible a greatly dynamic situation by rotary speed changes, and is also very simple and reliable. The direct influence of the rotary speed change on

the dosing leads to very short reaction times of the overall system.

An alternative to the disk shape or to the ring shape or to the hollow cylinder section is a slide-shaped portioning element that executes a to-and-fro swinging motion. Besides motor drives, whose rotational motion has to be converted to linear motion, according to the present invention, a swinging electromagnet would also be conceivable as the drive.

In order to ensure that the pellets are supplied individually and one after the other to the carrier air stream, the receiving elements are adjusted to the shape and the dimensions of the pellets in such a way that, in each case, only one pellet will fit into them.

For blowing out the pellets, according to one advantageous specific embodiment of the present invention, the cross section of the blow-out opening is formed to be larger than the receiving element, which makes blowing out the pellet easier.

One preferred specific embodiment of the present invention provides that the transport line, in which a carrier air stream for transporting the pellets is produced, has a slightly bigger cross section than the maximum size of the pellets would require. In this way, when transporting the pellets, the "blow-pipe" effect comes in useful, that is, in the transport tubing, the pellets form a kind of displaceable plug which almost completely fills the cross section of the transport tubing and thus closes it. The carrier air acting upstream generates an overpressure in the transport line which is the cause of the transport of the pellet in the transport line. This kind of transport has the advantage that bridge building by the material to be transported is excluded.

Furthermore, there is no hovering of the material in the carrier air stream, since the carrier air stream pushes the pellet ahead of itself like an air cushion. In this manner one may successfully route the transport line both uphill and downhill in narrow windings without experiencing interferences or fluctuations in the dosing of the pellets.

One specific embodiment of the present invention is also preferred in which the portioning element is partially covered by a baffle. In this context, the baffle takes on a scraper function and thereby prevents jamming and squeezing the pellets during the isolation procedure. Additionally, the compressed air nozzle for the carrier air stream may be integrated into the baffle, so that the baffle takes care at the same time of sealing the carrier air stream to the inside of the container.

In a further design according to the present invention, as many receiving elements as possible are provided on a circumferential line of the portioning element. This has the advantage that, for dosing, a slight rotational speed of the portioning element is sufficient, and therefore filling the receiving elements is managed with great certainty. The possible number of receiving elements is mainly determined by the radial distance of the receiving elements from the rotational axis and the mutual clearance from one another. The minimum mutual clearance of the receiving elements, according to one specific embodiment of the present invention, may be greater than the diameter of the compressed air nozzle, so that one achieves that in each case only one receiving element has air pressure applied to it. It is also possible to select the clearance to be slightly smaller, so that, independently of the setting of the portioning element, a carrier air stream constantly prevails in the transport line.

One preferred specific embodiment of the present invention provides forming the clearance of the receiving elements from one another greater than the diameter of the compressed air nozzle, and at the same time continuously to introduce air into the transport line at a location downstream from the compressed air nozzle. For this, for example, a part of the compressed air stream may be conducted upstream from the compressed air nozzle in a bypass line to the transport line. This makes certain that the pellets are blown out one after another from the receiving elements, and at the same time that there takes place a continuous carrying off in the carrier air stream. Thereby the efficiency and the operating safety of the device according to the present invention are increased.

The pressure prevailing in the transport system advantageously exceeds the environmental pressure at the output location of the pellets from the transport line. From this comes about the advantage that no air from the outside can get into the dosing device and the transport device, with which there would always be connected the danger that moisture could penetrate the system from the outside. In the case of operating standstill, i.e. when the engine is shut down, a blocking element may additionally be present that takes over the function of air-tight cutting off from external influences.

The transport of the urea using an air stream or gas stream offers the additional advantage that the urea is cooled during its transport and is protected from moisture. If necessary, only dry air is used for the carrier air stream, which is, for example generated in an air conditioning compressor.

Since, in the course of time, clogging of the receiving elements cannot be completely excluded, according to one particularly advantageous specific embodiment, the present invention is outfitted with a cleaning mechanism for the

receiving elements. The cleaning mechanism has one or more cleaning pins which, in the course of the movement of the portioning element, penetrate the just-emptied receiving elements, and in this context, push possibly remaining pellets or pellet remains from the receiving element. In this context, the cleaning pins may be located either supported at shiftable lengths and driven via a cam lobe on a shaft, or they may be located on a cleaning wheel uniformly distributed on the circumference and having a radial alignment.

Brief Description of the Drawings

The present invention is described in greater detail below, using an exemplary embodiment represented in the drawings.

The figures show:

Fig. 1 a schematic representation of a dosing and transporting device according to the present invention for carrying out the SCR method,

Fig. 2 a spatial representation of the storage vessel having the dosing device of Figure 1,

Fig. 3 a vertical section through the bottom part of the storage vessel having the dosing and transporting device, along line III-III shown in Figure 4,

Fig. 4 a horizontal section through the apparatus shown in Figure 3 along the line IV-IV shown there and

Fig. 5 an isometric representation of a specific embodiment of the dosing device having an integrated cleaning mechanism.

Ways to the Embodiment of the Present Invention and Industrial Application

In schematic representation Figures 1 and 2 show equipment for dosing and transporting dry urea for carrying out the SCR method. The equipment includes a storage vessel 1, which is used to store a large number of urea pellets 2. Storage vessel 1 has a cylindrical section in its upper part, which narrows, going downwards, in the shape of a funnel. At the lowest point on storage vessel 1, dosing device 3 is situated. Dosing device 3 will be explained in greater detail with respect to Figures 3 and 4. Finally, on the lower side of dosing device 3 there is a motor 4 as the drive for dosing device 3.

Transporting pellets 2 from storage vessel 1 is done with the aid of a compressed air source 5, such as in the form of an air compressor, which is connected to dosing device 3 via pressure line 6. An additional pressure line 7, for transporting pellets 2, connects dosing device 3 with a reactor 8, in which the conversion of urea pellets 2 to ammonia takes place, due to the effect of heat. The generated ammonia is finally introduced via line 9 into the exhaust gas stream of an internal combustion engine.

Figures 3 and 4 show dosing device 3 with parts of the transporting device. First is seen the lower, funnel-shaped part of storage vessel 1, which ends in a cylindrical extension 10. Cylindrical extension 10 surrounds, in a force-locking and gastight manner, dosing device 3, which, in this way in the case of the specific embodiment selected in the exemplary embodiment, forms the bottom of storage vessel 1.

Dosing device 3 has a circular disk 11, which closes flush with the lower edge of cylindrical extension 10. At its

circle center a concentric circular opening 12 is provided. Axis of rotation 13 runs through the center, and perpendicular to the plane of circular disk 11. Eccentrically, approximately between the center and the edge of circular disk 11, a bore 14 goes through the disk element, with its axis parallel to axis of rotation 13.

Towards the inside of storage vessel 1, adjoining to circular disk 11, there is a plane-parallel and coaxially situated portioning disk 15 which has at its lower side, facing circular disk 11, an extension 16 in the form of a short cylindrical piece, that extends from the middle of the lower side. Portioning disk 15 is located with extension 16 in opening 12, while maintaining a minimal play. In this context, circular disk 11 forms a sliding bearing for portioning disk 15, on which it is supported rotatably about axis of rotation 13.

Portioning disk 15 has a large number of parallel axis bores, which extend from the upper side of portioning disk 15 to its lower side, and which are situated uniformly distributed along a common circumferential line. Each of the bores forms a receiving element 17 for one pellet 2 in each case. The radial distance of receiving elements 17 from the axis of rotation 13 is equivalent to the radial distance of bore 14 from the center of circular disk 11, so that by turning portioning disk 15, receiving elements 17 may be brought one after another into a position aligned with bore 14.

Above portioning disk 15, a roughly ring-shaped baffle 18 is seen, that is also plane-parallel, which keeps such a great distance from circular disk 11 that portioning disk 15 is able to rotate within this space. The outer edge of baffle 18 adjoins the inner wall of cylindrical extension 10, and the inner edge, over the greatest part of its circumference,

traces a concentric circle which, in axial projection, overlaps with the outer edge of portioning disk 15. In this context, however, receiving elements 17 remain freely accessible from the inside of vessel 1. Only in the area of bore 14 is baffle 18 enlarged segmentally, so that bore 14 is covered in a planar manner in portioning disk 15.

In the direction of axis of symmetry 19, there extends, both through extension 10 of storage vessel 1 and through baffle 18, a radial bore 20, which ends above bore 14 of portioning disk 15. Perpendicular to bore 20, an additional bore 21, that is parallel to axis of rotation 13, has been introduced into baffle 18, that is aligned with bore 14 in circular disk 11, and which forms a continuous channel with bore 20. In this way, baffle 18 is used together with bores 20 and 21 to form a compressed air nozzle.

Pressure line 6, coming from pressure source 5, is connected to this bore 20. The compressed air stream is marked by arrow 22. Pressure line 7 is connected to bore 14 in circular disk 11, and it leads to reactor 8 (Figure 1). The carrier air stream prevailing in pressure line 7 is marked by arrow 23.

The drive required for the rotation of portioning disk 15 is taken care of by a rotary speed-controlled electric motor 4, which is fastened to the lower side of circular disk 11, directly below opening 12, and whose drive shaft 24 penetrates in a form-locking manner into short cylindrical piece extension 16. The direction of rotation of portioning disk 15 is given by arrow 25.

During the operation of the motor vehicle, in order to carry out the SCR method, a certain quantity of ammonia is supplied to the exhaust gas stream, as a function of the respective load state of the internal combustion engine. According to

the present invention, the quantity of ammonia required is brought about by conversion of urea pellets 2 in reactor 8. In this context, in order constantly to supply reactor 8 with a sufficient quantity of urea, pellets 2 are supplied from a storage vessel 1, in the quantity that is required at any particular moment.

To do this, it is first necessary to isolate pellets 2 that are present in bulk in storage vessel 1. Because of the force of gravity, lowest pellets 2 lie, making contact, on the upper side of portioning disk 15 that is surrounded by baffle 18 and is freely accessible. The isolation of the pellets takes place in that pellets 2 reach receiving elements 17 of portioning disk 15 as a result of their gravity. This process takes place along with the continuing rotation of portioning disk 15, in each case only one pellet 2 reaching receiving elements 17, as a result of the size of receiving elements 17. From here on, the pellets located in receiving elements 17 are marked 2'. The maximum speed of rotation of portioning disk 15 is limited because pellets 2 require a minimum of time to occupy receiving elements 17.

During the course of rotation of portioning disk 15, receiving elements 17 filled with pellets 2' are one after the other brought into a position in which their upper side lies opposite compressed air nozzle 18, 20, 21, and their lower side is aligned with bore 14. Since compressed air is applied to compressed air nozzle 18, 20, 21, pellets 2', upon reaching this position, are blown out of receiving element 17, and get into transport line 7. At this stage, the pellets are marked 2".

By the continuing rotation of portioning element 15, a receiving element 17, that has been blown out and is therefore empty, after passing through the region covered by baffle 18,

arrives again at storage vessel 1 to be filled, while another receiving element 17, occupied by a pellet 2' is taken to compressed air nozzle 18, 20, 21, where the blowing out of next urea 2' takes place.

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The individual receiving elements 17 in portioning disk 15 are separated by crosspiece regions of predetermined width.

During the rotation, receiving elements 17 and crosspiece regions are alternately passed by compressed air nozzle 18, 10 20, 21, the crosspiece regions having the effect of interrupting compressed air stream 22. In this way there is created an intermittent carrier air stream 23. By positioning there a bypass line, not shown, which connects pressure line 6 to transport line 7, an intermittent compressed air surge may 15 be generated at the exit of nozzle 18, 20, 21, with continuous transport of pellets 2" in transport line 7.

This type of isolation has the effect that pellets 2' reach transport line 7 in a sequence in time, which leads to a 20 spatial clearance of pellets 2" in transport line 7. By the adjustment of the internal diameter of transport line 7 to the dimensions of pellets 2, air cushions form in transport line 7 between two subsequent pellets 2" which are separated and limited by individual pellets 2", and between which, with 25 respect to each other, no considerable air exchange takes place. One speaks here of a "blow-pipe effect", which ensures that urea pellets 2" in transport line 7 maintain a predetermined clearance and do not bump into one another, which could subsequently cause bridge building and clogging. 30 The size of the air cushion gives the clearance between two pellets 2" in line 7, and is a function of the air quantity that gets from receiving elements 17 to transport line 17 during and between the blowing out of two subsequent pellets. The air cushions push pellets 2" ahead of themselves, 35 independently of the course of transport line 7, even any

desired differences in height and curve radii being managed,
until pellets 2" are finally fed into reactor 8.

The change in dosing of the urea is made via a rotary speed
5 change of portioning disk 15. By increasing the rotational
speed, pellets 2' get into transport line in a shorter
sequence in time. By contrast, if the rotational speed is
slowed down, a reduction in dosing may be achieved. In this
way, for example, without any problem, a dosing of 0 pellets
10 per second to 40 pellets per second is possible, which is
equivalent to a mass flow of 0 g per hour to approximately 600
g per hour. Since a rotary speed change of driving motor 4,
and thus of portioning disk 15, leads directly to a change in
dosing, an adaptation of the quantity of urea to changing load
15 states of the internal combustion engine may be made very
accurately and with great dynamism.

Since it may not be completely excluded that receiving
elements 17 become partially or completely clogged in the
20 course of time with pellets 2 or pellet remains, according to
one preferred specific embodiment of the present invention,
dosing device 3 is outfitted with a cleaning mechanism 26,
which is postconnected to compressed air nozzle 18, 20, 21 in
the direction of motion of portioning element 15, and which
25 will be explained in more detail in the light of Figure 5.

Because of greater clarity, Figure 5 shows only dosing device
3, without storage vessel 1, pressure lines 6 and 7 and drive
motor 4. One may see portioning disk 15, having receiving
30 elements 17, situated rotatably about axis of rotation 13,
between circular disk 11 and baffle 18. From the lower side
of portioning disk 15 there extends, centrally, short
cylindrically shaped extension 16, which penetrates into
opening 12 of circular disk 11. Short cylindrically shaped
35 extension 16 is surrounded concentrically by a toothed rim 32,

which is connected fixedly to the lower side of portioning disk 15, and which forms a part of an angle drive.

1 The other part of the angle drive includes drive shaft 27,
5 which is supported, freely rotatable, in circular disk 11,
below portioning disk 15, perpendicular to axis of rotation
13. At the inner end of drive shaft 27 there is a frustum-
shaped pinion 28, whose teeth engage with toothed rim 32. In
addition, on drive shaft 27, affixed with force-locking, there
10 is a cleaning wheel 29 that is provided uniformly over its
circumference with radially aligned cleaning pins 30. To
accommodate drive shaft 27, pinion 28 and cleaning wheel 29, a
corresponding hollow space is formed in circular disk 11 which
is continued to the lower side of circular disk 11, and which
15 forms an opening 31 there.

The arrangement of cleaning mechanism 26 within dosing device
3 is such that, with respect to the rotational movement 25 of
receiving elements 17 it is postconnected to compressed air
20 nozzle 18, 20, 21, and that the distance of cleaning wheel 29
from portioning disk 15 makes possible the penetration of
receiving elements 17 by cleaning pins 30.

During the operation, described before, of the device
25 according to the present invention, the rotational movement 25
of portioning disk 15, initiated by drive motor 4 via toothed
rim 32, is transmitted to pinion 28 and further on to drive
10 shaft 27 and cleaning wheel 29. Consequently, rotational
motion 25 of portioning disk 15 runs synchronously with
30 rotational motion 33 of cleaning wheel 29 having the cleaning
pins situated on it. By the suitable arrangement of cleaning
pins 30 on cleaning wheel 29, in this context, in each case a
cleaning pin 30 engages with a receiving element 17, and
possibly lifts pellets 2' or pellet remains that may be
35 present out of receiving element 17. Urea particles that

appear in this context, because of gravity, fall through opening 31 and out of dosing device 3. In this way it is permanently ensured that there are always available empty receiving elements 17 for the isolation and dosing of pellets 2 that are located in storage vessel 1.